Challenges to Agentization of the Battlefield

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Abstract. The anticipated dynamics of the future battlefield will require greatly increased mobility, information flow, information assimilation, and responsiveness from a tactical operation center (TOC) and platforms (tanks, armored personnel carriers, etc.). This paper illustrates the potential synergy between these seemingly disparate developments, particularly related to battlefield visualization, multi-resolution analysis, software agents, and physical agents. Battlefield visualization programs are currently focussed on representing the physical environment. This greatly contributes to situation awareness at the TOC and platform levels. As intelligent agents, both software and physical agents, are developed, battlefield visualization must be enhanced to include the state, behavior, and results of the actions of these agents. Multi-resolution data and analysis will enhance visualization, software agent and physical agent performance. There are significant challenges to the integration of these technologies and to creating an effective human/multi-agent interaction.

Introduction

There is widespread dissatisfaction with the design and functionality of current Army tactical operation centers (TOCs) [4]., due primarily to their lack of mobility, inefficiency, and high complexity. The extensive hardware, software, and manpower resources needed to operate a current TOC severely limit the required mobility needed for a future nonlinear, dynamic battlefield. A greatly increased level of automation is needed both to significantly lower the human resources required and to improve information flow. For this level of automation to be accepted battlefield commanders must be comfortable with the control and believe in the automated approach. Figure 1 depicts the size and mobility envisioned for a future TOC.

The TOC exists to support the tactical commander in understanding the current state of the battlefield and in predicting its future state. It also provides planning, monitoring, and reaction functions to the commander. The situation awareness that results enables rapid and effective decision making and leadership. Although the

TOC is the information and control center of the tactical battlefield, it must also be able to project its critical information to a commander on a remote platform such as a tank or helicopter, observing or interacting with vital positions on the battlefield. Because the TOC is an information integration and fusion node, it is an essential part of a highly distributed and mobile force. A scalable, extensible, and adaptable visualization and software agent architecture and rich application set are required to

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achieve the increased efficiency envisioned. Most low-level information retrieval, dissemination, and analysis will be performed or controlled by these agents.

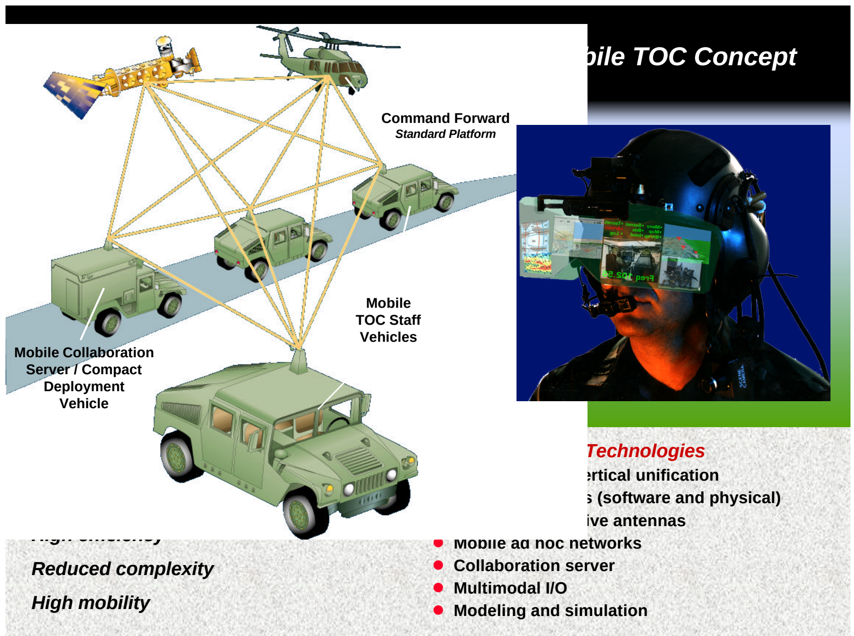

Figure 1. Mobile future TOC concept.

Battlefield visualization technology and software agent technology are closely linked because of the need to visualize and interact with both the agents and the results of their analysis. Automated communications between the TOC and its associated platforms (human or robotic) will be agent based. The digitization of the lower echelons of the army strongly enhances the coupling of the TOC and the tactical platforms, enabling the automated exchange of data and information, as well as access to more advanced applications by means of an agent environment. This automated information exchange will greatly reduce the latency of information, reduce uncertainty, and enable a more real-time control system approach in the battlefield. Figure 2 illustrates this exchange, where agents are classified according to their battlefield functional area.

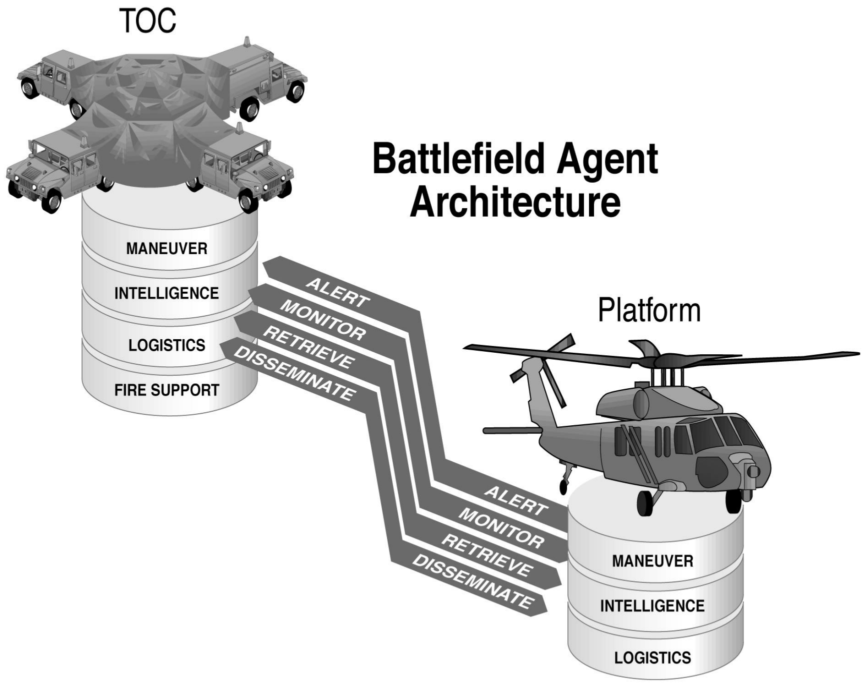

Figure 2. TOC-platform agent interaction.

Physical agents are expected to be ubiquitous on the future battlefield, significantly lowering the risk to our soldiers. They will be present in a myriad of shapes, sizes, and capabilities. Because these physical agents are to complement future manned systems, they must be able to collaborate not only amongst themselves but also with their manned partners. Their missions will range from scout missions (reconnaissance, surveillance, and target acquisition) to urban rescue. Robotic sentinels and remote communication systems would reduce the soldier workload of a future TOC. Teams of small robots deployed by manned or unmanned mother ships will explore (for hazards) and define buildings before manned occupation. Figure 3 depicts an urban scenario [1]. The Army has both cross-country and urban mission robot programs in development. Robust mobility, collaborative military behavior, and effective soldier robot interaction are major development areas. These robots must be able to operate in these battlefield environments approximately at the same tempo as the manned forces.

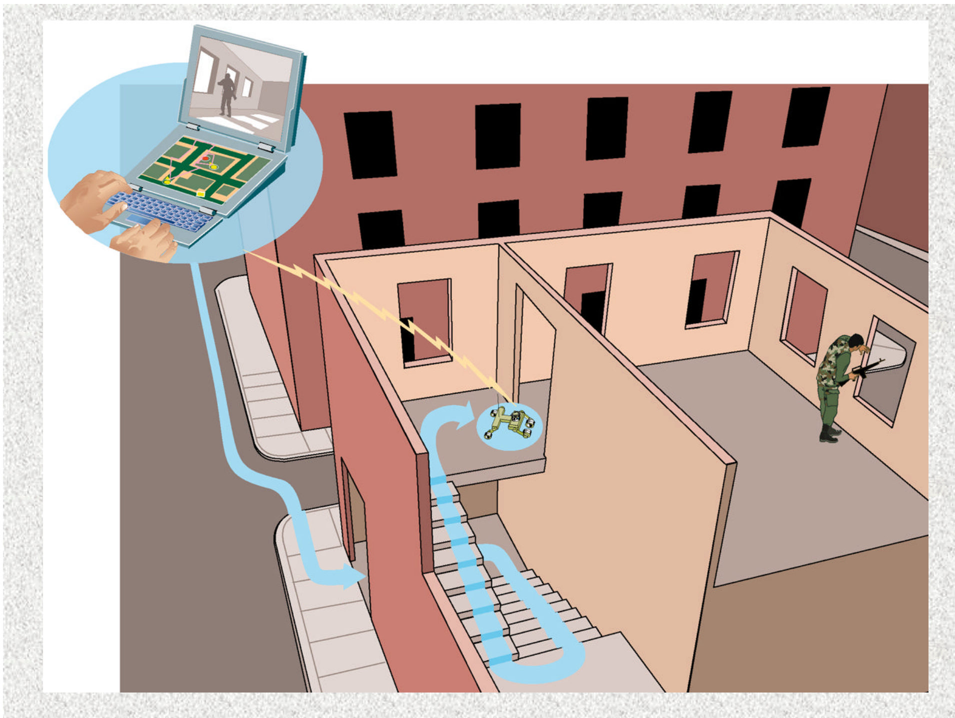

Figure 3. Small robot urban scenario

The information gathered by these agents will be sent to a mother ship or TOC and be visualized by human controllers. The high-level control and interaction between the mother ship and its agents will be based on software agent technology, analogous to the TOC/platform interaction. Software agents will be monitoring the robot disposition and communicating with the robot controller. A future combat system could be augmented by these small robots, thereby increasing its urban effectiveness.

Software Agent Applications

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Figure 4 illustrates the relationship between software agent applications and visualization. Software agents provide much of the analysis of battlefield data. Both the results of this analysis and the state and behavior of these agents need to be visualized. Of the myriad possible battlefield agent applications, this paper focuses on several that require scalability and extensibility of the agent approach.

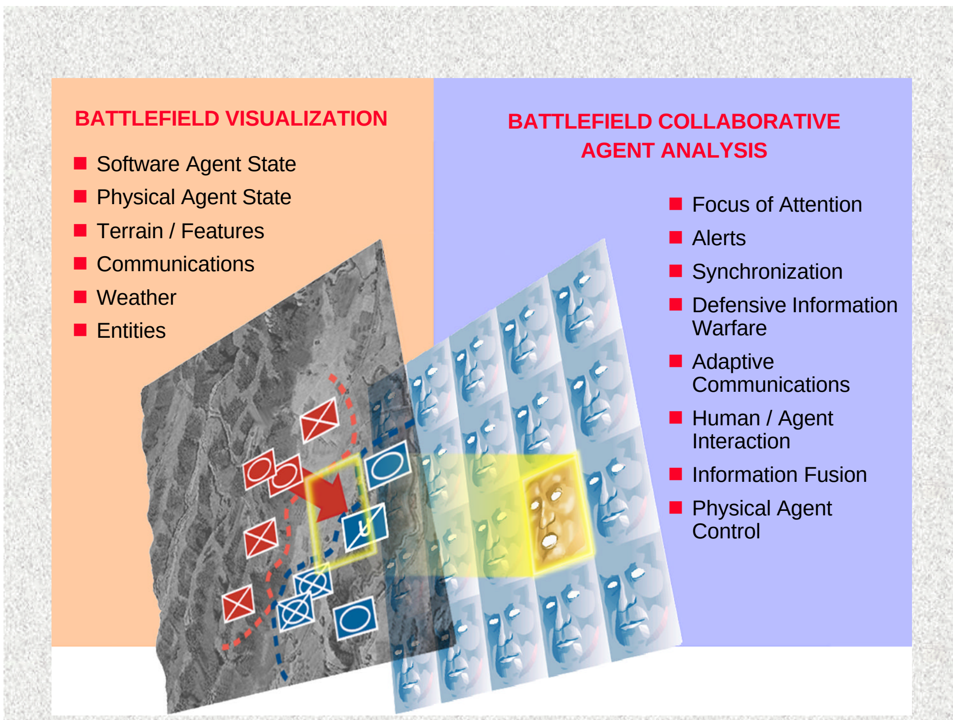

Figure 4. Intelligent agent battlefield applications and visualization.

Consider initially the basic sentinel application, where agents must be able to dynamically monitor and analyze battlefield activity and perform alert functions. These agents are assigned to monitor either fixed areas on the battlefield or areas associated with entities (fixed or moving). The following are two examples of monitor agents scenarios:

1. Assign an agent to monitor a specific area of interest where if enemy armor is detected in force before the blue force occupies the nearby hills, the blue commander and the maneuvering units must be alerted. This agent, although fixed spatially, must have spatial and temporal reasoning.

2. Assign an agent to monitor a maneuvering blue force battalion, and alert it if any enemy radar is capable of detecting it as it performs its planned maneuver path. This agent has mobility (not fixed to a geographic area) in addition to spatial reasoning.

Although these sentinel agent applications seem simple, significant temporal and spatial reasoning is required to minimize unnecessary alerts.

Now consider a broader agent application scenario. The TOC brigade commander has selected a maneuver course of action plan that calls for the synchronized movement, enemy engagement,and logistics resupply of the brigade. The plan has been disseminated and the maneuver platforms have begun executing this course of action. This plan implementation stimulates significant agent activity both in the TOC as well as in the maneuver platforms. A global maneuver monitor agent in the TOC interacts with the maneuver monitor agents in the platforms. The platform synchronization monitor agents have the task of alerting the human platform commander if the maneuver entity cannot execute its maneuver plan. This agent would also alert the TOC maneuver monitor agent of any execution problems. A TOC intelligence agent continuously monitors and retrieves any pertinent enemy information that would affect this operation. For example, suppose a radar is detected near the planned path of one of the maneuver battalions. This intelligence agent alerts both the TOC maneuver plan agent as well as the affected platform agents (maneuver and intelligence). At the TOC, a fire support agent generates an attack plan to disable this enemy sensor asset. This plan is presented to the TOC commander and is refused because the commander considers the available fire support assets insufficient. At the affected platforms, the platform maneuver agent generates a reactive maneuver plan and if acceptable to the local commander, the plan is executed. A platform logistics monitor agent keeps track of local resources (fuel, ammunition, spare parts, etc.) and disseminates this information to the TOC logistics agent. The TOC logistics agent continuously monitors the resupply plan that supports this engagement. If the planned resupply points become inadequate because of excessive engagement times or maneuver, the TOC logistics agent redefines the resupply points.

This example application indicates that monitoring, alerting, dissemination and retrieval agents are needed for each of the major battlefield functions (such as maneuver, intelligence, and logistics) at both the TOC and the lead platforms. Many applications are possible within each of the functional areas. Some of which may differ, within each functional area such as maneuver, at the TOC and the platform. Because of the complexities inherent in creating and interacting with a large set of agents, it is essential that the human/agent interaction be intuitive and not cumbersome. Since many agent applications will be oriented toward entities or areas in the battlefield, an effective battlefield visualization approach representing the agents and their behaviors is essential.

Battlefield Visualization

We introduce here a multi-resolution approach to visualization as well as analysis. Most of the current emphasis of the Army battlefield visualization program is on providing a global infrastructure with the ability to visualize the battlefield

environment (terrain, weather, entities, features, communications, etc.) at whatever resolution is required and available. This enables the commander to have a custom global view of the battlefield as well as a high-resolution local view to support critical decisions. This same infrastructure supports high-fidelity local views for the platform commanders as well as the ability to jump to any other local view in the world (as long as data is available) to support training or preparation for deployment. This scalability provides a single visualization approach suitable for both TOC and platform applications, including robotic platforms. Figure 5 illustrates a coupled 2D/3D visualization approach.

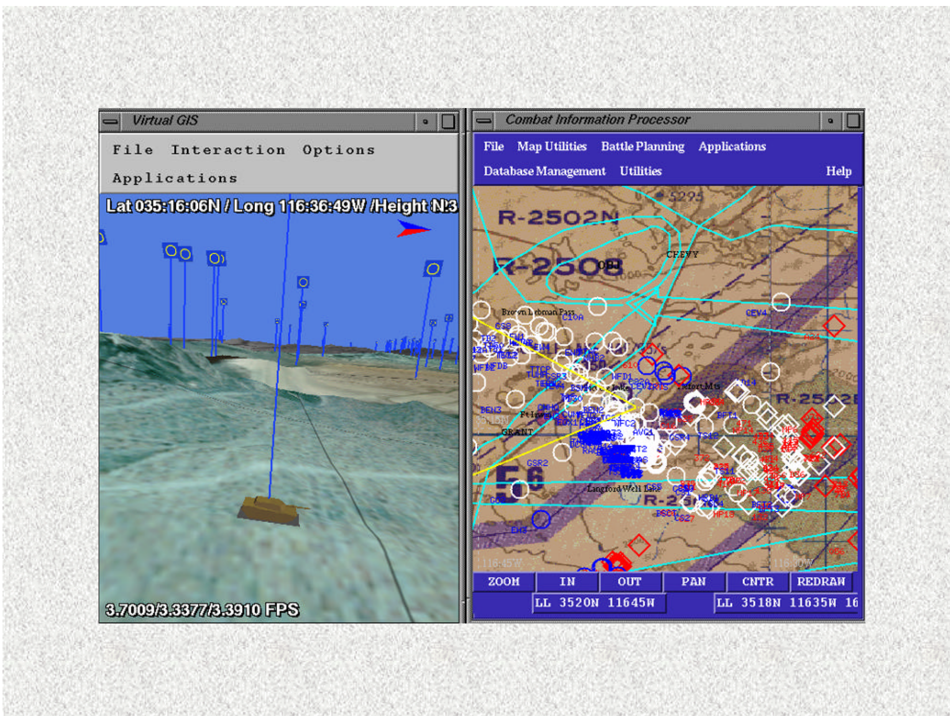

Figure 5. Coupled 2D/3D visualization.

A 2D/3D approach in necessary since soldiers are very familiar with two-dimensional maps and can maintain their global situation awareness. However the 2D representation is not as effective for visualization of high-resolution, complex terrain. 3D representation is excellent for high-resolution, complex terrain, but it is very easy to lose a global perspective (get lost) in all the detail presented. Presenting both views simultaneously eliminates many of the problems inherent in a single-view approach. Many sources of environmental data are available, albeit with widely varying resolution and coverage. It is therefore necessary for any visualization system to work with multresolution data (elevation and imagery). Software agents will use this

multiresolution data for responsive planning and mission execution. While robots do not visualize, they must reason about their environment. Although the robotic platforms will have effective local perception, this multiresolution environmental data will enable them to create reactive plans(implemented by software agents), similar to the agent activity in human platforms.

Military planners currently use digital terrain and elevation data along with digital feature data to plan. Because the currently available elevation data are so coarsely sampled (100 m or 30 m post spacing), these planned routes may contain numerous, significant obstacles. In order to traverse these routes, the manned or unmanned vehicles must sense and react to these obstacles. As the number of reactions increases, the time to complete the mission also increases. Fortunately, under the battlefield visualization umbrella, there are programs, that are developing the technology to both rapidly generate and visualize much higher resolution data (1 m). This would enable an operator to visualize the planned routes and manually detect obstacles. If the planning and execution analysis could use the high-resolution data, then many of the obstacles that fall within the 1 to 100 m range could be detected and avoided in the plan. However, the cost for this high-resolution analysis is increased processing time, since the route-planning algorithms would be using much more data. A multiresolution analysis would use high-resolution data only when the environmental complexity required it. This would greatly decrease the processing cost for most areas. Because the cost for reactive planning is high, particularly in robotic platforms, significant mission savings (time) are expected. Figure 6 illustrates the need for high-resolution data.

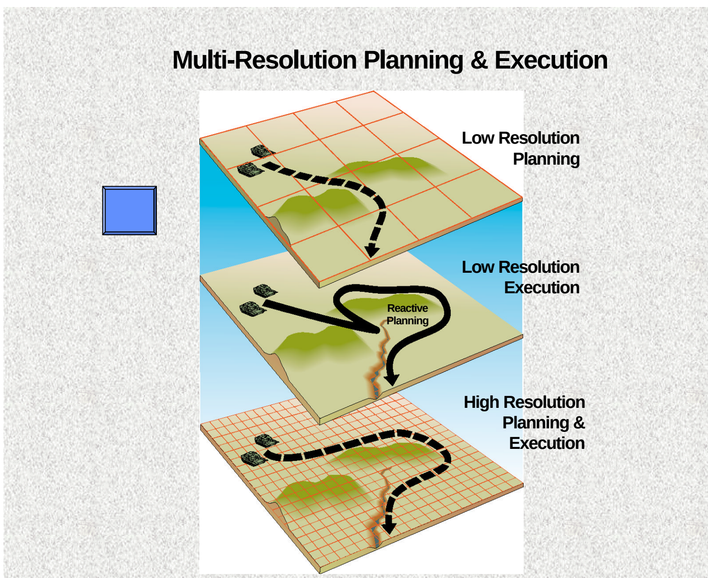

Figure 6. Multi-resolution planning

The original plan developed with 100 m elevation post spacing does not recognize a significant obstacle to the planned maneuver. With 1 m data, the resultant plan does not require reactive planning.

Agent/Visualization Implementation

The Army Research Laboratory (ARL) and the University of Maryland (UMD) have recently integrated a software agent architecture with a 2D/3D multiresolution visualization research testbed [3]. The University of Maryland has developed a software agent architecture called Interactive Maryland Platform for Agents Collaborating Together (IMPACT) [2,5], and ARL has developed a large-scale battlefield visualization testbed, the Combat Information Processor (CIP). IMPACT was used to agentize the legacy client/server-based CIP and provide the initial sentinel agent functionality described in this paper. This functionality was added by agentizing the CIP control measure and entity servers. Figure 7 represents the human computer interface of this agent application.

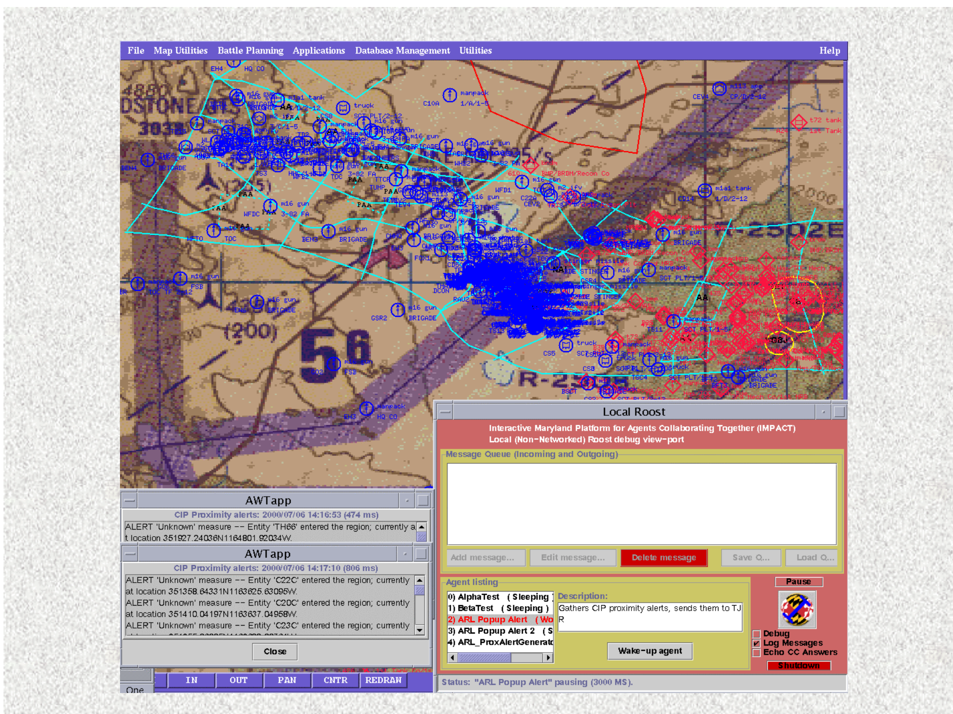

Figure 7. Sentinel visualization interface.

Conclusions

The Army must take advantage of the synergy between its visualization, software agent, and physical agent technology developments. Without a holistic approach, multiple competing visualization and software agent designs will proliferate. Even with a single optimal design approach for human/agent interaction, this research and development must address the ability of the human controller to assimilate and act on the state of the battlefield and direct his agents rapidly enough to satisfy future battlefield dynamics. Figure 8. Presents a block diagram of an integrated system.

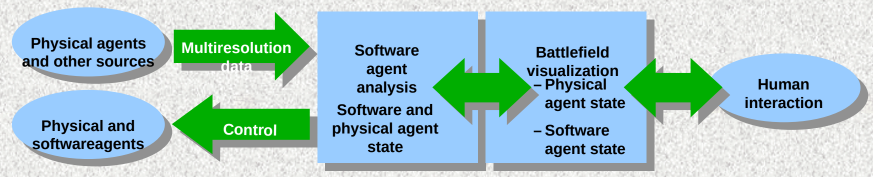

Figure 8. Battlefield Visualization, Software Agent, and Physical Agent Integration

An effective physical and software agent interaction would be perceived to be non-intrusive and would provide all the necessary focussed information for rapid decision making. A software agent application architecture may be sufficient to perform many of the manpower intensive tasks at both the TOC and the individual platforms. These tasks have been categorized similarly to the battlefield functional areas. Although myriad applications are possible, spanning a widely dispersed level of complexity, a number of low-level applications can also be very effective in TOC automation. It is critical that the agent approach be scalable, extensible, and adaptable to address the broad application area of the tactical battlefield. Many of these tasks can be implemented with generic low- level monitor, alert, retrieve, and disseminate functions. Although these functions seem simple, significant temporal and spatial reasoning is required to prevent overly encumbering the commander or his staff. For example if the commander sets an alert based on enemy activity in a region, it would be acceptable to alert him when the threshold of activity is reached. However, if additional activity is sensed, should the commander continue to be alerted? If the pattern of activity changes (temporally, spatially, or organizationally) are new alert warrented?

There still is concern that the human/agent interaction may be too encumbering for the commanders and staff involved. Closely coupling the agent interaction with battlefield visualization should make the interaction more intuitive. Also, an embedded training application for decision making that uses an this agent approach will accelerate the acceptance of this approach. This embedded training would include the ability to rapidly construct scenarios to continuously improve the commander's and staff's decision making. If this training capability is embedded, the operators will automatically train on the use of this agent approach and develop a trust in these agents.

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